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Fatigue Behavior of Hybrid Nano Composites CNTS/Graphene Reinforced E-Glass

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***Abstract*—The present project work deals with the fabrication and characterization of reinforced bidirectional woven E-glass fibre/epoxy composites enhanced by multiwalled carbon nanotubes and graphene. In the present study three process parameters were considered such as nanofillers ranging from 0.1,0.2 and 0.3 weight percentage of multi-walled carbon nanotubes (MWCNTs) and Graphene powder (Gnps), process to disperse hybrid nanoparticles in epoxy resin and in addition to by orienting bidirectional woven E-glass reinforced woven fabric in longitudinal(0^0/90°) and 45^0 direction. Finally mechanical properties such as Compressive, Tensile and Flexural testing carried out by using servo hydraulic instron machine for hybrid nanocomposites.**

Index Terms—Hybrid nano composites, CNTS, grapheme, nano tubes, e-glass

I. Introduction

Fibers or particles embedded in matrix of another material are the best example of modern-day composite materials, which are mostly structural. Laminates are composite material where different layers of materials give them the specific character of a composite material having a specific function to perform.

Fabrics have no matrix to fall back on, but in them, fibers of different compositions combine to give them a specific character. Reinforcing materials generally withstand maximum load and serve the desirable properties.

Composites cannot be made from constituents with divergent linear expansion characteristics. The interface is the area of contact between the reinforcement and the matrix materials. In some cases, the region is a distinct added phase. Whenever there is interphase, there has to be two interphases between each side of the interphase and its adjoint constituent. Some composites provide interphases when surfaces dissimilar constituents interact with each other. Choice of fabrication method depends on matrix properties and the effect of matrix on properties of reinforcements. One of the prime considerations in the selection and fabrication of composites is that the constituents should be chemically inert non-reactive.

II. Experimental Part

After preparing the epoxy-MWCNT's/Graphene suspension mixed with required amount of hardener (10 wt. % of epoxy. The volume percentage of matrix and fibres 75 and 25 respectively. By using hand –layup method prepared the laminates. Followed by curing at 60°C and applied pressure 1 MPa in hot compressed press for 20 min. Likewise, using the same parameters for prepare MWCNT's/Graphene as well as Glass epoxy composites. For preparing hybrid glass epoxy composite, 14 layers glass fibre and required amount of epoxy and hardener. Laminate was cut for flexural test (as per ASTM D3039) by using diamond tipped cutter. The samples were then post-cured at 80 °C for 6 hr. Pre-calculated MWCNT and Graphene was slowly poured into 150 mL of acetone. By using magnetic stirring the suspension was stirred at room temperature for 30 min at 1000 rpm. Followed by sonication for 30 min. Because of stirring and sonication, the MWCNTs and Graphene gets distributed throughout suspension.

Mechanical stirring: Epoxy base is a blue colour thick fluid. It is quite difficult to mix nanoclay into it manually. So we used a mechanical stirrer and an oil bath for proper mixing of nanoclay Oil bath was used to heat up the epoxy to desired temperature for reducing the viscosity of epoxy base. Proper mechanical stirring of epoxy at this stage resulted better dispersion of clay. Different percentage of clay 5%, 2%, 3% and 4% by weight were added and stirred at 60 C for 2 hours. After sonication the suspension was mixed with precalculated epoxy. Magnetic stirring of epoxy/CNT/Graphene/acetone mixture was done at 1000 rpm for 4 hour at 80 °C. Sonication was again carried out at 80 °C upto evaporate entire acetone. During process might be air bubbles entrapped into the suspension. To remove these air bubbles, suspension was vacuum degassed for 18 hrs. The figures show the dispersion of MWCNTs and Graphene in composite and fabricate the fibre reinforced nanocomposite. After ultrasonication, the solution is mixed with the hardener in the ratio 5:2 by volume. After mixing; mechanical stirring up to 5 to 10 minutes was done.

After the fabrication of composite laminates, we have cut those composite laminates into pieces as per ASTM standards required dimensions for tensile, compression and flexural tests.

III. Results and Discussion

Tensile tests are used in selecting materials for engineering applications. Tensile properties frequently are included in material specifications to ensure quality. Tensile properties often are measured during development of new materials and processes, so that different materials and processes can be

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compared tensile properties often are used to predict the behavior of a material under loading tension. The test specimen is subjected to the jaws of the instron 8801.

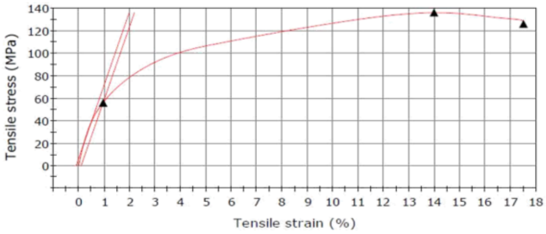


Fig. 1. Tensile stress vs Tensile Strain of 0.1 wt % MWCNTs

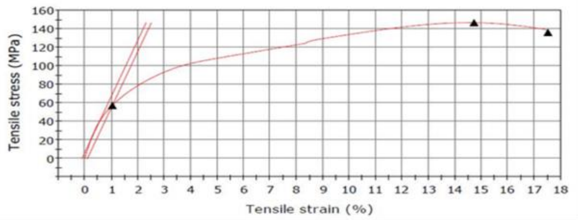


Fig. 2. Tensile stress vs Tensile Strain of 0.2 wt % MWCNTs

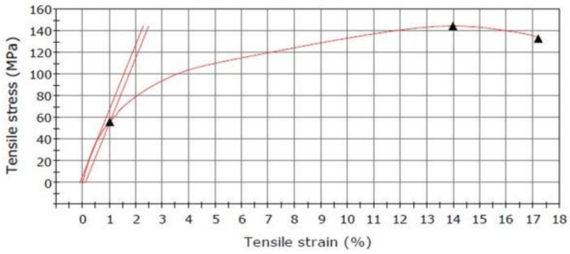


Fig. 3. Tensile stress vs Tensile Strain of 0.3wt % MWCNTs

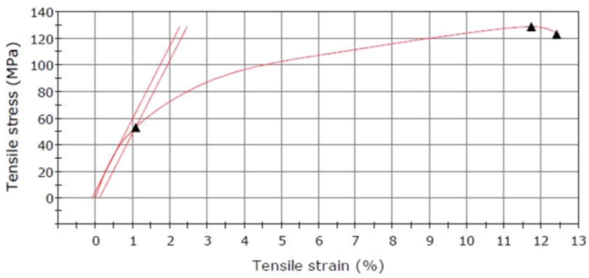


Fig. 4. Tensile stress vs Tensile Strain of 0.1wt% GNPs

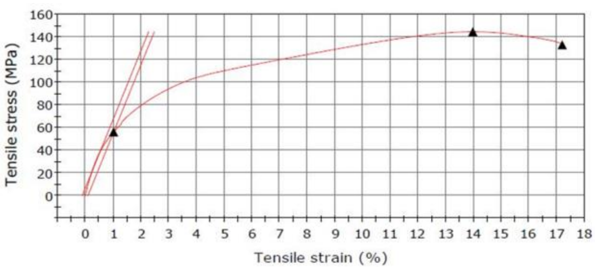


Fig. 5. Tensile stress vs Tensile Strain of 0.2wt % GNPs

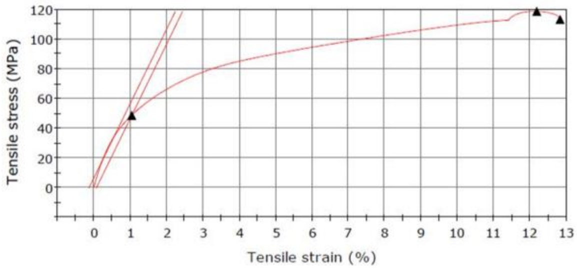


Fig. 6. Tensile stress vs Tensile Strain of 0.3wt % GNPs

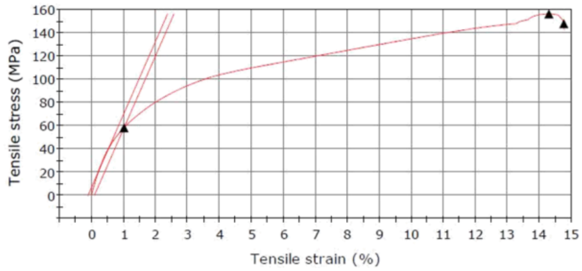


Fig. 7. Tensile stress vs Tensile Strain of 0.1wt % MWCNTs/GNPs

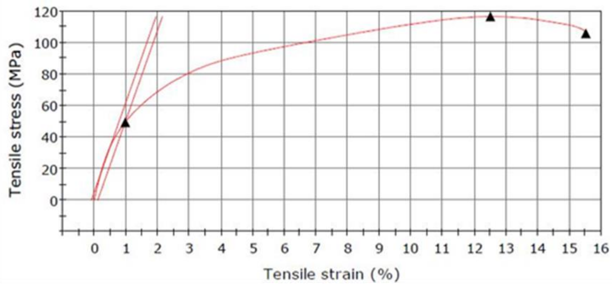


Fig. 8. Tensile stress vs Tensile Strain of 0.2wt % MWCNTs/GNPs

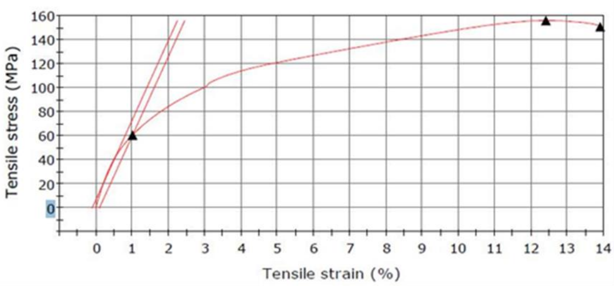
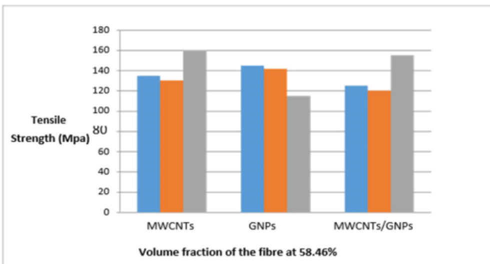


Fig. 9. Tensile stress vs Tensile Strain of 0.3wt % MWCNTs/GNPs



Composition	MWCNTs	GNPs	MWCNTs/GNPs
0.1 wt %	135	130	160
0.2 wt %	145	142	115
0.3 wt %	125	120	155

Fig. 10. Comparison of MWCNTs, GNPs and MWCNTs/GNPs with different composition

From the above graph we concluded that in the MWCNTs the 0.2wt % composition of specimen have high strength, if further add the mixture then its strength is decreasing. In the GNPs the 0.2wt% composition of specimen have high strength, if further composition is increased then the strength is decreasing. In the combination of MWCNTs and GNPs the 0.1 wt% of specimen have high strength as compare to the remaining. If further mixture increases then its strength is decreasing.

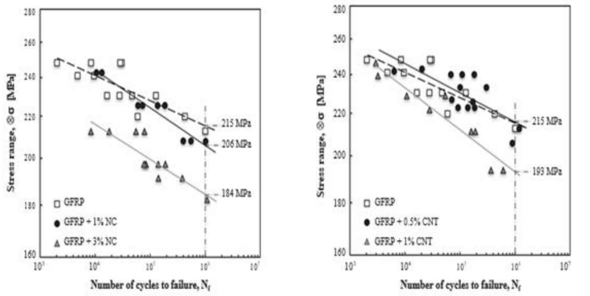


Fig. 11. Effect of nano clay and carbon nano tubes addition on GFRP composites under three point bending fatigue loading

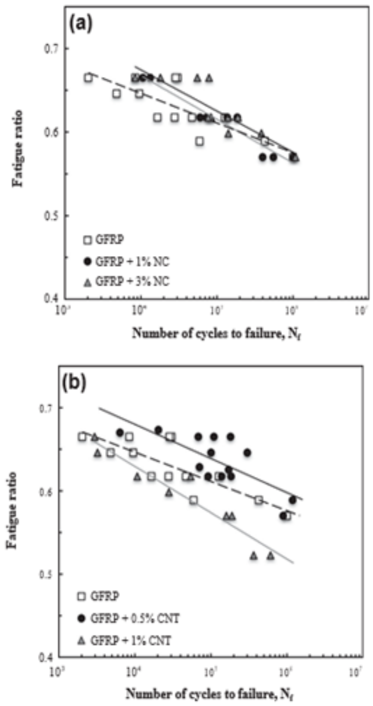


Fig. 12. Fatigue ratio against the number of cycles to failure under 3 PB loading: (a) Nano clay filled GFRP (b) Carbon nano tube enhanced composite

The fatigue results obtained under tension–tension loading, analysed in terms of the stress range of the load cycle against the number of cycles to failure, are depicted in Fig. 13, for glass fibre reinforced polymers with addition of nano clays or carbon nanotubes into the epoxy matrix, respectively. The fatigue life for neat epoxy matrix glass fibre reinforced composites is once again superimposed in both figures for comparison.

A close proximity is observed between the *S*–*N* curves of the neat matrix glass fibre reinforced epoxy composite and of nano particle enhanced composites, suggesting that under tension–tension fatigue loading the particle addition does not affect significantly the performance of the resulting composites since the mechanical resistance is mainly due to the fibres disposed in the loading direction. However, it is still noticeable that in terms of average values the higher amounts of nanoparticles added composites display a slightly lower fatigue resistance. Indeed, for both the 3% nanoclay and 1% car- bon nanotube enhanced GFRP composites the fatigue strength at 10^6 cycles decreases approximately 3% relatively to the neat epoxy matrix GFRP. On the other hand, Fig. 13, clearly shows approximately the same fatigue strength at 10^6 cycles as the one achieved by the neat glass fibre reinforced composite for both 1% nanoclay and 0.5% MWCNT enhanced GFRP composites.

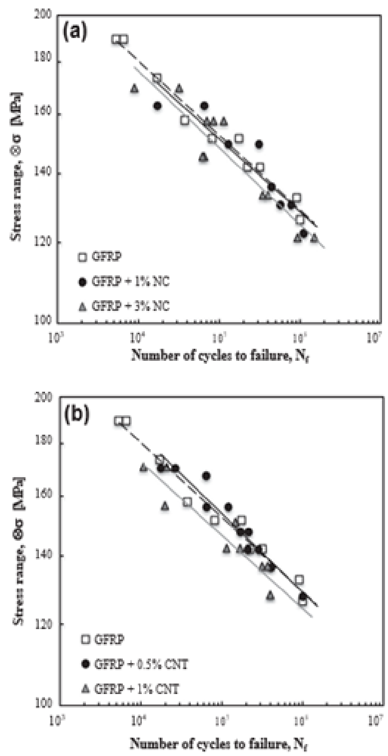


Fig. 13. Effect of nanoparticle addition on GFRP composites under tension-tension fatigue loading: (a) Nano particles and (b) Carbon nanotubes

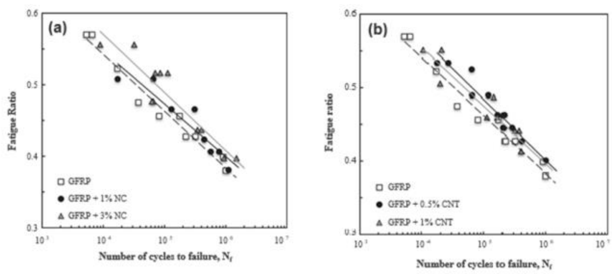
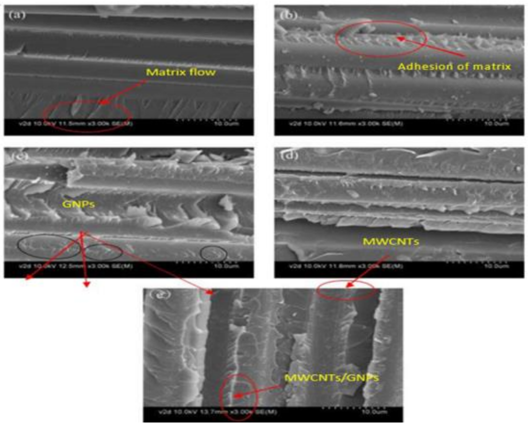


Fig. 14. Fatigue ratio against the number of cycles to failure under tension-tension loading: (a) Nano clay filled GFRP and (b) Carbon nanotube enhanced composite

A. Fractrography of MWCNTs,GNPs and MWCNTs/GNPs

A Scanning Electron Microscope (SEM) is a tool for seeing otherwise invisible worlds of microspace (1 micron = 10^{-6}m) and nanospace (1 nanometer = 10^{-9}m). By using a focused beam of electrons, the SEM reveals levels of detail and complexity inaccessible by light microscopy. SEMs can magnify an object from about 10 times up to 300,000 times. A scale bar is often provided on an SEM image. From this the actual size of structures in the image can be calculated.



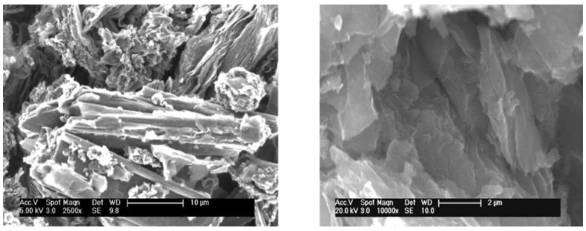


Fig. 15. SEM images of the graphene powder at different magnifications with scale bars (A) 50µm, and (B) 2µm

IV. Conclusion

This project has investigated the importance of stress studies in epoxy composites reinforced with the CNTs (Graphenes and MWCNTs) to elucidate the reinforcing ability of the CNTs in an epoxy matrix. This project was undertaken to synthesize and characterize MWCNTs and determine the effect of different weight fractions of untreated MWCNTs on the stress transfer efficiency at the MWCNTS / epoxy interface and on the stiffness on the mechanical properties of the MWCNTS / epoxy composites. It was undertaken to assess the stress transfer efficiency at the CNT / epoxy interface and at the inter-walls of the CNTs with tensile deformation and with cyclic loading. The morphology was observed by SEM for GNPs and MWCNTs, showing a high density of clusters of web-like ropes and approximately 83 ± 5 wt % and 98 wt % carbon purity, respectively, based on SEM analysis. For the MWCNTs, chunks (arrays) of entangled tube bundles were obtained approximately 87 wt% carbon pure based on SEM analysis.

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